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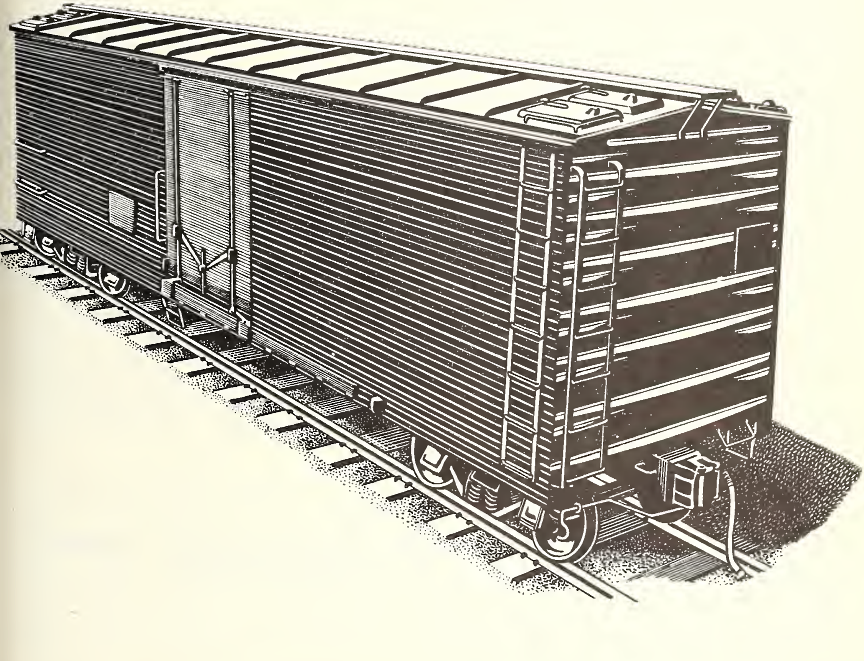
A PERFORMANCE TEST OF REFRIGERATED RAIL CARS

Transporting Frozen Food



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SUMMARY

This report is based on a study of the comparative performances of two types of mechanical refrigerated rail cars and a standard water-ice and salt refrigerated car hauling packaged frozen corn from Waseca, Minn., to Jersey City, N. J. Performances are measured in terms of precooling time, air, and commodity temperatures within the cars, and out-of-pocket refrigeration costs.

In the mechanical refrigerator cars precooling times varied widely; one car required approximately 7 hours, the other 16 hours to reduce interior car temperatures to 0° F. Contributing to this was the difference in the refrigerating capacities of the cars. At 100° ambient temperature and 0° interior temperatures, one car was rated at 52,000 British thermal units per hour compared with 32,000 B. t. u./hr. in the other. No precooling test was conducted on the water-ice car since it was not available for instrumentation before initial icing.

Comparatively high and variable temperatures were recorded in the water-ice-salt car. During transit, the refrigerating system absorbed only a very small part of the heat gained by the commodity during loading and while on origin siding. The commodity temperature had increased from 0° F. to an average of 14.6° upon completion of loading. Air temperatures were well above the desired 0° level. At destination the average commodity temperature of the test packages was 14.3°, approximately the same level at which the commodity left Waseca.

The transit test for both mechanical cars was divided into 2 parts: the first with thermostats set at 0° F., and the second with thermostats lowered to -10°. The object was to check further the capacities of the refrigerating units. During the first part of the transit test, air and commodity temperatures changed little. The fact that thermostats were not identically calibrated resulted in some variance in temperatures between the cars, but recorded commodity temperatures were within a satisfactory range. On the second part of the trip, temperatures declined rapidly in both cars indicating the refrigeration systems had ample reserve capacity and were capable of maintaining 0° temperatures.

During the tests, the twin engines in one of the mechanical cars operated intermittently a total of 112 hours. They consumed 123.5 gallons of fuel, at an estimated cost of $19.76. In the second mechanical car, the single engine operated continuously for 130.9 hours and consumed 97.4 gallons of fuel at an estimated cost of $15.58. Contributing to this difference in fuel consumption was the greater capacity of the refrigeration system in the first car, the greater cargo load, and the fact that somewhat lower average temperatures were maintained in it. Seventeen tons of ice and 5 tons of salt were put in the ice car bunkers. At railroad tariff rates the charges for that amount of ice and salt would have been $214.97. Actual railroad costs for ice and salt are not known.

Consumption of fuel, ice, and salt represents only one of many factors in total operating costs. The original cost of the mechanically refrigerated car is much higher than the standard ice bunker car, and the cost of amortization over its service life undoubtedly would be considerably greater. Maintenance costs of mechanical cars may be assumed to be higher than for ice cars. However, data on these additional costs are not available.

A PERFORMANCE TEST OF REFRIGERATED RAIL CARS TRANSPORTING FROZEN FOOD

By Russell H. Hinds, Jr., Harold D. Johnson,
and Robert C. Haldeman, Transportation and
Facilities Branch, Agricultural Marketing Service

Rapid expansion in the movement of packaged frozen foods by refrigerated cars over great distances has brought problems in protecting the quality of the commodity in transit. Research on the temperature tolerances of frozen foods has indicated the necessity for maintaining 0° F. or lower in-transit temperatures to maintain as closely as possible the inherent nutritive food qualities. The generally inadequate supply of the comparatively new mechanically refrigerated cars and the resulting use of many water-ice and salt cars in shipping frozen food have accentuated the problem of maintaining proper temperatures.

This transportation refrigeration test was conducted to compare performances of two types of mechanically refrigerated rail cars and a standard water-ice and salt refrigerated car hauling frozen corn from Waseca, Minn., to Jersey City, N. J. Performances are measured in terms of precooling times, air and commodity temperatures within the cars, and ice, salt, and fuel, or out-of-pocket, refrigeration costs.

EQUIPMENT STUDIED

The 3 cars are designated as follows:

1. Water-ice and salt car - "A" (fig. 1).
2. Mechanical unit car - "B" (fig. 2).
3. Mechanical unit car - "C" (fig. 3).

Car A was a 50-foot end-bunker water-ice refrigerator car with 6 inches of glass fiber insulation in the side walls, ceiling, and floor (fig. 1). Outside sheathing was steel and the inside was wood. The floor racks were 7½ inches deep, constructed with lengthwise steel stringers and wood floor slats, laid in a herringbone pattern. The steel stringers contained numerous holes to permit better air circulation. Wall racks had 1- x 2-inch wood supports vertically attached to the side walls, spaced 12 inches on centers, and 1- x 2-inch horizontal members attached to the vertical strips, 8 inches on centers.

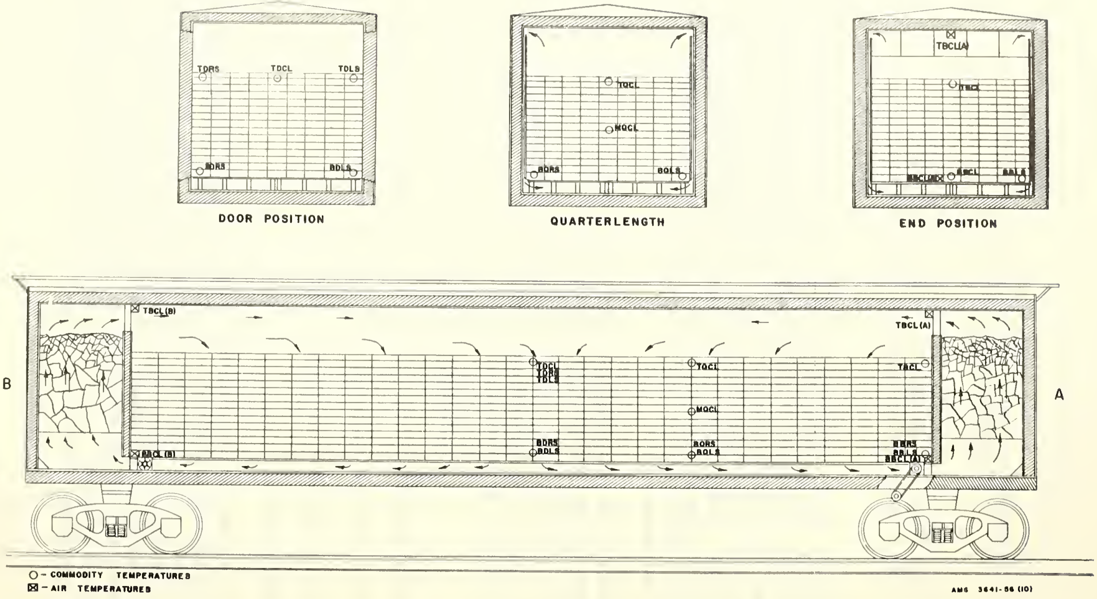


Figure 1.--Car A, a 50-foot water-ice refrigerated railroad car, loaded with packaged frozen corn. The locations of the electrical resistance and air temperature recording thermometers also are shown. For explanation of TDRS, TDCL, etc., see pages 7-8. A and B identify the ends of the car.

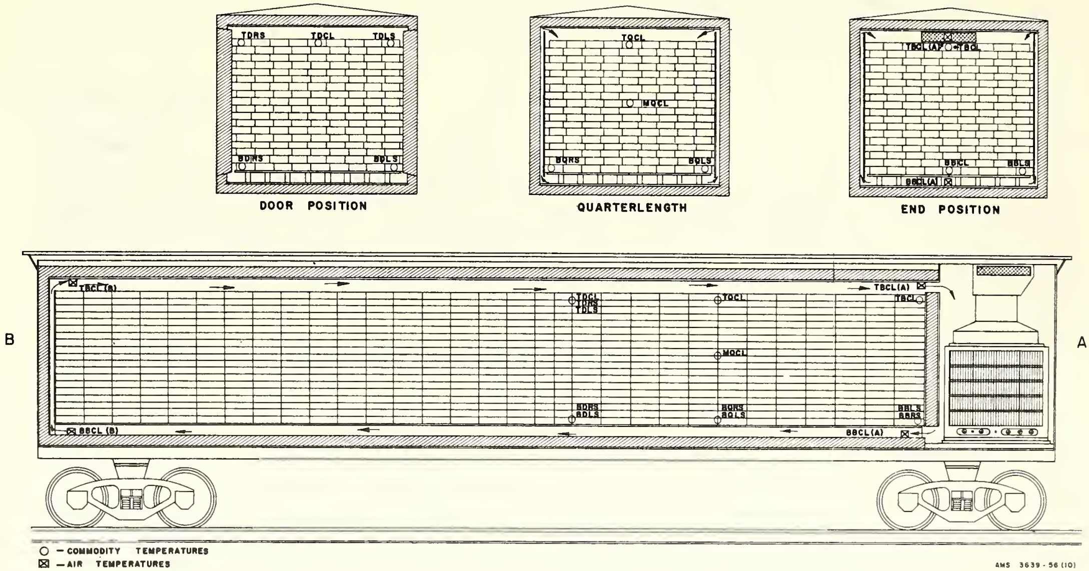


Figure 2.--Car B, a 50-foot mechanically refrigerated railroad car, loaded with packaged frozen corn. The locations of the electrical resistance and air temperature recording thermometers also are shown. For explanation of TDRS, TDCL, etc., see pages 7-8 A and B identify the ends of the car.

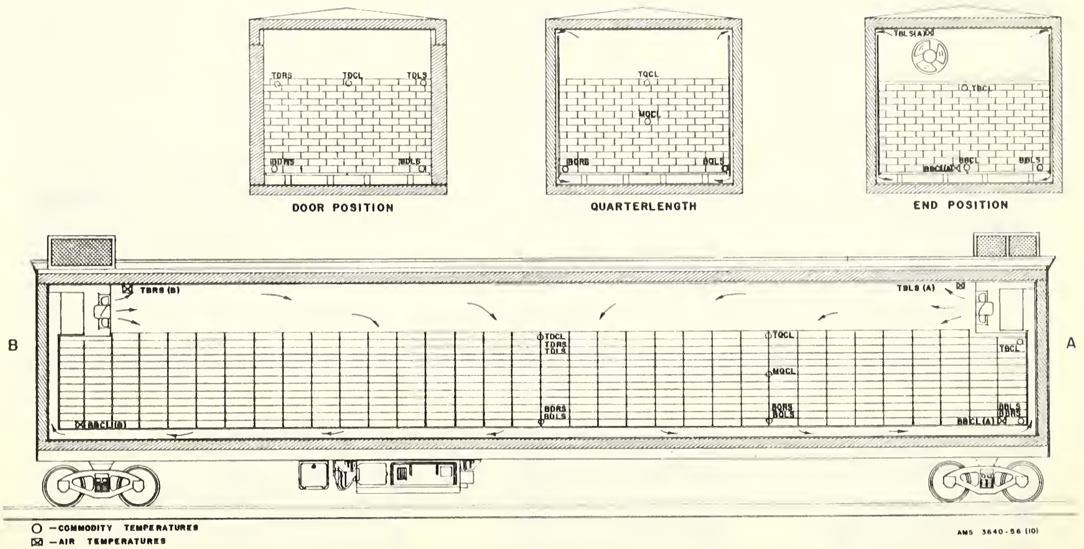


Figure 3.--Car C, a 50-foot mechanically refrigerated railroad car, loaded with packaged frozen corn. The locations of the electrical resistance and air temperature recording thermometers also are shown. For explanation of TDRS, TDCL, etc., see pages 7-8. A and B identify the ends of the car.

Air circulation was provided by fans located under the floor racks at each end of the car. The fans extended the full width of the car, sucking air from the load and blowing it into the bottom of the ice bunker. The air was chilled as it passed up through the ice. At the top of the bunker it was blown out into the cargo area. The power for operating each fan came from a small wheel whose surface could be engaged to that of a car wheel by means of a lever. The rotary motion was then transmitted through a V-belt to the fan shaft. When air circulation was not desired, the V-belt could be disengaged. Thermostatic controls are not used on water-ice cars. The ice bunkers had a rated capacity of about 15,000 pounds of ice.

Mechanical car B was 50 feet long, with 6 inches of glass fiber insulation in the ceiling, walls, and floor (fig. 2). Exterior sheathing was steel and the interior was wood. Refrigeration was supplied by twin mechanical units mounted at one end of the car, each controlled by a separate thermostat. These units were housed in a compartment separate from the cargo space. Both units discharged refrigerated air through a common duct that had an opening under the floor racks at one end of the car. The air intake for both units was a single opening near the ceiling directly above the blower outlet. The opening to this intake was equipped with a metal guard, preventing shifting cargo from blocking the return air entrance.

The floor racks were 7 inches high and were made of solid plywood. They had lengthwise wooden stringers, containing numerous holes to permit better air circulation. The racks formed a large duct under the entire load. The walls were the false wall or flue type, forming what is commonly called an "envelope of cold" around the cargo. Refrigerated air left the blower, passed under the floor racks and up behind the false wall, then into the top of the cargo area; from there it returned through the intake to the evaporator coils.

Each of the twin refrigeration units was powered by a 25 hp. 4-cycle gasoline-type engine burning diesel fuel. They had a combined rated capacity of 52,000 British thermal units per hour (26,000 B. t. u./hr. for each unit) at 100° F. ambient temperature and 0° inside the car. The engines were equipped with fuel and manifold heaters to facilitate direct starting with diesel fuel, even in cold weather. Each engine starter was activated by the controlling thermostat and these were attached to the ceiling directly in front of the air intake opening. In this location, they were activated by the circulating air as it returned to the evaporators for further cooling. In general practice, the thermostat for one unit is set about 5° lower than the other so that one operates only during peak loads. For this test, the thermostats were set the same, but because of minute differences in thermostat settings the units did not operate simultaneously throughout the tests.

Mechanical car C (fig. 3) was similar to car B. Insulation and outside dimensions were the same. However, the floor racks in this car were 6½ inches high with longitudinal steel stringers containing holes for air circulation, and covered with 1-inch by 4-inch slats spaced 1 inch apart. The side walls were the false wall type.

Electrical power to operate the 2 cooling-heating units was supplied by a 42 hp. 4-cycle horizontal diesel engine directly connecting with a 220-volt, 3-phase, 60-cycle alternator. The diesel engine and alternator were mounted beneath the car. Each of the condensing units and evaporator coils was mounted at opposite ends on top of the car. They were self-contained and produced 32,000 B. t. u./hr. (16,000 B. t. u./hr. for each unit) at 100° F. ambient temperature and 0° interior car temperature. Each was fitted into a space ordinarily occupied by the ice hatch doors. The condensing units were above the roof surface and the evaporators extended down into the cargo area. The evaporator fans circulated refrigerated air from both ends of the car across the load, down behind the false walls, under the floor racks, and returned it to the evaporator intakes.

The diesel engine on this car ran continuously, compared with the intermittent operation of the engines in car B. It operated at idling speed until more refrigeration was needed; then the thermostat caused it to accelerate and the condenser-evaporator units began operating. These units continued to operate until the temperature in the car was lowered to the thermostat setting. When the setting was reached, the engine reverted to idling speed and the cycle was completed. The controlling thermostat bulb was located on the ceiling centerline, approximately 4½ feet from the side door.

PROCEDURE

An electrical resistance thermometer was used in each car to determine temperatures of the product. This instrument had 12 thermometer bulbs that were inserted directly into the product. Wires led from these bulbs to the ceiling and were attached to a master cable that ran from one end of the car to the center door. A short section near the end of this cable was flattened and coated with protective rubber. This permitted it to be compressed as the door was closed. Thus, it did not interfere with the air seal on the door and temperature readings within the car could be taken without opening the door. The end of the cable was equipped with a 12-terminal plug attached to a multiple selector switch so that temperature readings could be taken at 12 locations in the car. The positions of the electrical resistance thermometer bulbs in the 3 cars were the same and are indicated in figures 1, 2, and 3. The locations and designations are as follows:

Location	Description
1. Bottom bunker centerline	BBCL
2. Top bunker centerline	TBCL
3. Bottom quarter right side	BQRS
4. Top door right side	TDRS
5. Top door centerline	TDCL
6. Bottom door left side	BDLS
7. Bottom door right side	BDRS
8. Top door left side	TDLS
9. Bottom quarter left side	BQLS
10. Middle quarter centerline	MQCL
11. Top quarter centerline	TQCL
12. Bottom bunker left side	BBLS

Except for the one thermometer bulb placed in the middle quarter centerline position, all bulbs were placed in packages located in outer stacks and layers of the cargo load. It is in these outer stacks and layers that the commodity would first be affected by heat gain or loss within the car. Therefore, the temperatures recorded at these 11 locations are believed to be representative of commodity temperatures in all cartons around the exterior of the loads. Temperatures recorded in the one test package within the interior of each load are believed to approximate the temperature of the commodity in other packages at interior positions; these temperatures are discussed separately, beginning on page 18.

Air temperatures were taken with recording thermometers at 4 locations in each car. These instruments were the windup clock type and used a continuous waxed tape and marking scribe for temperature recordings throughout the trip. Their locations and designations (figs. 1, 2, and 3) are as follows:

Location	Description
Car A	
1. Bottom bunker centerline, A end of car	BBCL (A)
2. Bottom bunker centerline, B end of car	BBCL (B)
3. Top bunker centerline, A end of car	TBCL (A)
4. Top bunker centerline, B end of car	TBCL (B)
Car B	
1. Bottom bunker centerline, under floor rack in front of blower, A end of car	BBCL (A)
2. Bottom bunker centerline, under floor racks, B end of car	BBCL (B)
3. Top bunker centerline, in front of intake, A end of car	TBCL (A)
4. Top bunker centerline, B end of car	TBCL (B)

Location	Description
Car C	
1. Bottom bunker centerline, A end of car	BBCL (A)
2. Bottom bunker centerline, B end of car	BBCL (B)
3. Top bunker left side, in front of blower, A end of car	TBLS (A)
4. Top bunker right side, B end of car	TBRS (B)

PRECOOLING TEST

Cars B and C were placed on a rail siding at Waseca, Minn., 2 days before the proposed precooling test. They had not been in service for several days and were empty, clean, and dry. In preparation for the precooling test, the car doors were opened for several hours to equalize interior temperatures, operation of the mechanical units was checked, and testing equipment was installed. The thermostats were set at 0° F., the doors closed, and the mechanical units started. Both units in car B and the unit in car C operated throughout the precooling test. Temperature data for this test were taken from recording thermometers located in the same positions as described above and on page 7. No precooling test was conducted on the water-ice car (A) since it was not available for the precooling test.

As shown in table 1, the average air temperature in car B was reduced from 77.5° to 0° F. in approximately 7 hours. In car C, reduction of the average air temperature from 78.5° to 0° required about 16 hours. While there were comparatively small differences between top and bottom air temperatures during the precooling test, temperatures in car C were more uniform than those in car B (figs. 4 and 5).

Contributing to the difference in time required for precooling was the greater refrigerating capacity of car B--52,000 B. t. u./hr. compared with 32,000 B. t. u./hr. in car C--under comparable conditions.

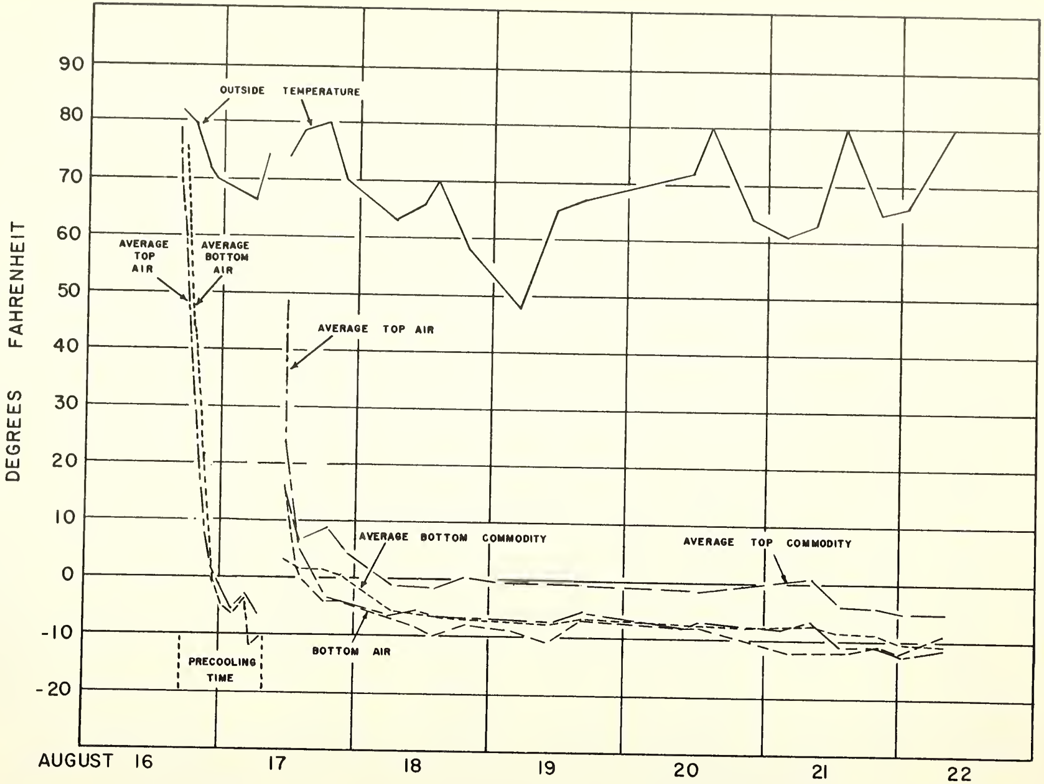
TRANSIT AND PULLDOWN TESTS

Before loading the cars, test packages in the cold storage warehouse were prepared for the thermometer bulbs. A hole the size of the thermometer bulb was drilled into the frozen commodity in 1 package in each of the 36 test cartons. This was done to insure an accurate temperature reading of the product and to avoid extra handling of these packages while loading. Commodity temperatures in test packages were checked and found to be between ±1° F. Loading began at 7:15 a.m., August 17, 1956, and as it proceeded, the test cartons were brought from the warehouse, placed at 12 locations in each car, and the thermometer bulbs inserted. This procedure was followed to minimize the effect of ambient heat on the frozen product.

Table 1.--Air temperatures during precooling test, August 16-17, 1956

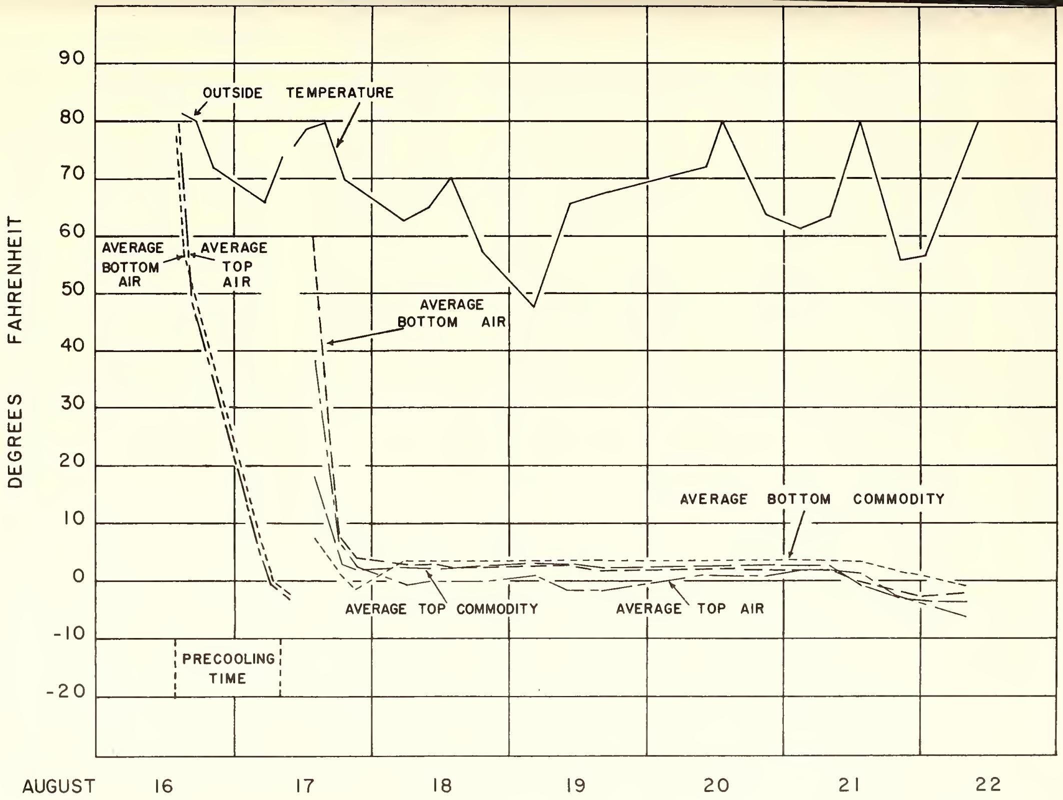
Date and time	Car B							Car C						
	Location 1/				Average air temperatures			Location 1/				Average air temperatures		
	TBCL (A)	TBCL (B)	BBCL (A)	BBCL (B)	Top	Bottom	Average	TBCL (A)	TBCL (B)	BBCL (A)	BBCL (B)	Top	Bottom	Average
	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.
August 16:														
4:00 p.m.	78	80	75	77	79.0	76.0	77.5	79	80	78	77	79.5	77.5	78.5
5:00 p.m.	65	62	60	60	63.5	60.0	61.8	70	70	70	68	70.0	69.0	69.5
6:00 p.m.	52	50	44	46	51.0	45.0	48.0	65	66	66	66	65.5	66.0	65.8
7:00 p.m.	40	35	35	35	37.5	33.5	36.3	55	55	56	53	55.0	54.5	54.8
8:00 p.m.	27	25	25	22	26.0	23.5	24.8	48	47	47	45	47.5	46.0	46.8
9:00 p.m.	15	15	15	12	15.0	13.5	14.3	43	40	42	40	41.5	41.0	41.3
10:00 p.m.	6	7	5	6	6.5	5.5	6.0	37	36	36	35	35.5	35.5	36.0
11:00 p.m.	2	1	-2	0	1.5	-1.0	.3	31	31	31	30	31.0	30.5	30.8
12:00	-1	-1	-7	-2	-1.0	-4.5	-2.8	27	26	26	25	26.5	25.5	26.0
August 17:														
2:00 a.m.	-6	-6	-8	-6	-6.0	-7.0	-6.5	17	16	16	16	16.5	16.0	16.3
4:00 a.m.	-4	-2	-1	-6	-3.0	-3.5	-3.3	17	10	10	10	10.5	10.0	11.8
6:00 a.m.	-5	-4	-16	-9	-4.5	-12.5	-8.5	5	4	5	5	4.5	5.0	4.8
8:00 a.m.	-6	-7	-12	-9	-6.5	-10.5	-8.5	-1	-2	0	0	1.5	0	-.8

1/ TBCL--Top bunker centerline; BBCL--bottom bunker centerline; A and B represent ends of car.



AMS 3638-56 (10)

Figure 4.--Outside temperature and average temperatures of the top and bottom of the load in car B during test.



AMS 3636-56 (10)

Figure 5.--Outside temperature and average temperatures of the top and bottom of the load in car C during test.

Each carton of frozen corn weighed 17½ pounds. Car A was loaded with 4,000 cartons, car B with 5,178 cartons, and car C with 4,000 cartons. The number of cartons loaded in each car was governed by the height to which they could be stacked and still allow sufficient space for cold air circulation over the top of the load.

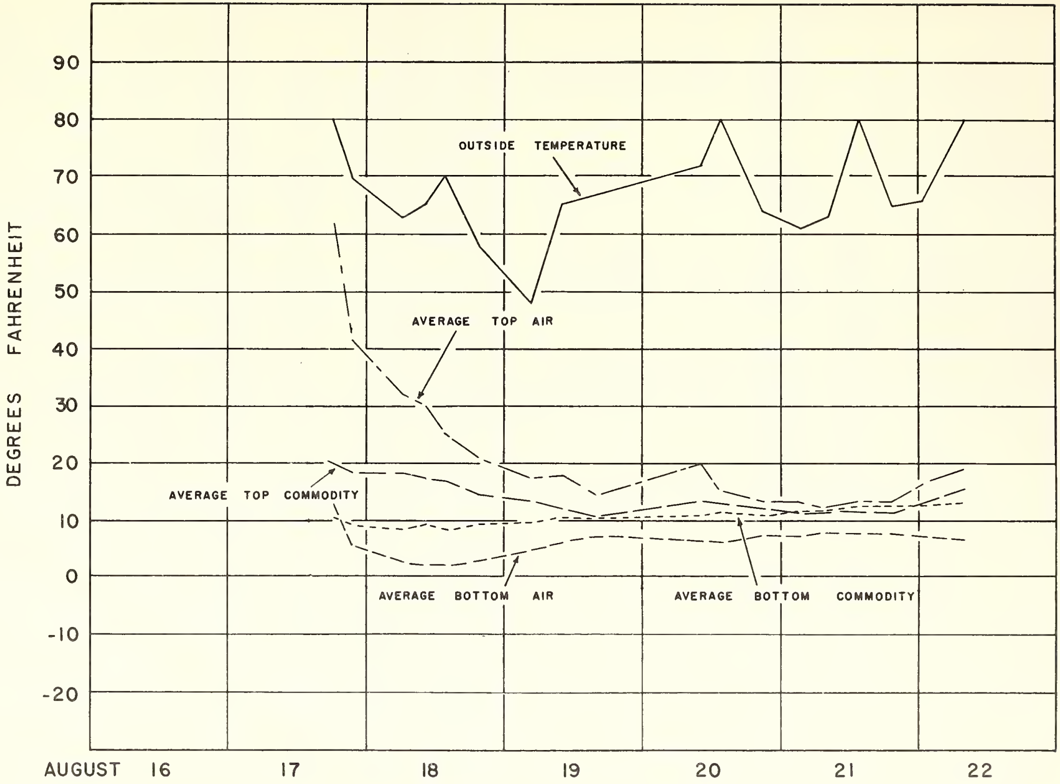
The bunkers in car A were filled with a mixture of ice and 30 percent salt the evening of August 16. Temperatures in cars B and C were maintained at 0° F. or lower until loading time. The cars were handled one at a time, each loading requiring approximately 3 hours. The water-ice car was loaded last to allow as much time as possible for precooling, and the interior air temperature averaged 11° just before loading (fig. 6). After cars B and C were loaded the doors were sealed, refrigerating units were started, and the initial temperatures were read. Loading was completed at 6:15 p.m., August 17. The fans in car A were not operating at this time, and forced air circulation was not provided until the car was in motion. The bunkers were re-iced and salted at 3:00 p.m., August 17.

The cars were picked up the following afternoon, August 18, at 2:00 p.m. by the C&NW Railroad and delivered to the IHB Railroad at Proviso, Ill., August 19, at 4:00 p.m. On August 20, at 10:15 a.m., they were transferred to the Pennsylvania Railroad at Dolton, Ill., and delivered to Harborside Warehouse, Jersey City, N. J., at 4:00 a.m., August 22. United States Department of Agriculture representatives accompanied the cars, taking product temperature readings en route. These representatives also collected data on fuel and ice consumption and observed the effectiveness of the insulation and the physical fitness of the cars. Final product temperatures were read at 8:00 a.m., August 22.

The corn used in this test was plate frozen and held in storage at 0° F. During loading, precautions were taken to keep the product cold. A curtain was used on the car doors around the loading conveyor, and palletized loads were moved rapidly from storage into the cars, but air temperatures increased as much as 65° in the car. This heat raised commodity temperatures in exterior test packages as indicated by the initially recorded temperatures shown in tables 14, 15, and 16.

Comparatively high and variable temperatures were recorded in the water-ice car (table 14). Several factors contributed to this: (1) The fan drive belt at the B-end of the car (fig. 1) was broken, and this fan did not operate throughout the trip 1/; (2) the fan at the A-end of the car operated only when the car was in motion. no portable power unit was used while the car was being precooled or during the 23 hours it was loaded and on siding at Waseca, Minn.; and (3) the salt was not thoroughly mixed with the bunker ice.

1/ Attempts to replace this belt were made, but it was impossible to remove the plate which covered the fan assembly without sending the car to a repair shop.



AMS 3637-56 (10)

Figure 6.--Outside temperature and average temperatures of the top and bottom of the load in car A during test.

As shown in table 2, the heat convection process resulted in only a small decline in commodity temperatures while the car was loaded and awaiting transit at Waseca, Minn. Top temperatures remained substantially higher than bottom temperatures. Bottom air temperatures were substantially below the top air temperatures throughout the trip. The average initial commodity temperature was 14.6°, and at destination it was 14.3° F., well above the 0° at which the commodity was loaded and only 0.3° lower than the initial average.

Table 2.--Average temperature changes in car A, loaded and awaiting transit at Waseca, Minn., August 17-18, 1956

Date and time	Commodity			Air		
	Top	Bottom	Average	Top	Bottom	Average
	°F.	°F.	°F.	°F.	°F.	°F.
August 17:						
6:30 p.m.	20.0	10.2	14.6	62.0	12.5	37.3
9:40 p.m.	18.4	9.0	13.3	41.5	5.5	23.5
August 18:						
6:30 a.m.	18.2	8.5	13.0	32.5	2.5	17.5
10:30 a.m.	17.2	9.0	12.7	30.0	2.0	16.0
2:00 p.m.	17.0	8.5	12.3	25.0	2.0	13.5
Change	-3.0	-1.7	-2.3	-37.0	-10.5	-23.8

Table 3 and figure 6 reveal that during the time in transit the refrigerating system in car A absorbed only a very small part of the heat gained by the commodity during loading and on the siding at Waseca, since air temperatures were well above the desired 0° F. Only air temperatures at the bottom of the bunker at the B-end of the car were near this level, averaging 1.3°. Had the heat gain at origin been less and had both fans operated, using portable motors while on the siding at Waseca, it is possible much lower temperatures could have been maintained.

Table 3.--Average temperature changes in car A while in transit, Waseca, Minn., to Jersey City, N. J., August 18-22, 1956

Location	Date and time	Commodity			Air		
		Top	Bottom	Average	Top	Bottom	Average
		°F.	°F.	°F.	°F.	°F.	°F.
Waseca	Aug. 18, 2:00 p.m.	17.0	8.5	12.3	25.0	2.0	13.5
Jersey City . .	Aug. 22, 8:00 a.m.	15.8	13.0	14.3	19.0	6.5	12.8
Change . . .		-1.2	+4.5	+2.0	-6.0	+4.5	-.7

Loading of car B was completed at 11:15 a.m., on August 17, and the loaded car remained on the siding until 2:00 p.m. the following day, or about 27 hours (table 4 and fig. 4). Average commodity temperature had increased from 0° to 8.6° during loading, the top averaging 15.2° and the bottom 3.2°.

By 6:30 a.m. on the following day, the average temperature was lowered to -3.5°, and by 2:00 p.m., when the cars were placed in transit, the average commodity temperature had declined to -4.3°. These recorded temperatures indicate that the car refrigeration system had ample capacity to lower temperatures rapidly.

Table 4.--Average temperature changes in car B, loaded and awaiting transit at Waseca, Minn., August 17-18, 1956

Date and time	Commodity			Air		
	Top	Bottom	Average	Top	Bottom	Average
	°F.	°F.	°F.	°F.	°F.	°F.
August 17:						
11:15 a.m. . .	15.2	3.2	8.6	48.5	1/	1/
2:00 p.m. . .	6.6	1.3	3.7	6.0	1/	1/
6:30 p.m. . .	8.8	1.5	4.8	-2.5	1/	1/
9:40 p.m. . .	5.2	.7	2.7	-4.0	1/	1/
August 18:						
6:30 a.m. . .	-.8	-5.6	-3.5	-6.5	1/	1/
10:30 a.m. . .	-1.0	-6.0	-3.7	-5.5	1/	1/
2:00 p.m. . .	-1.4	-6.7	-4.3	-6.5	1/	1/
Change . . .	-16.6	-9.9	-12.9	-55.0	1/	1/

1/ Instrument failed to record temperatures.

The transit test for both mechanical cars was divided into 2 parts, the first from Waseca, Minn., to Altoona, Pa., with thermostats set at 0° F.; the second from Altoona, Pa., to Jersey City, N. J., with thermostats set at -10°. The object of this procedure was to further check the capacities of the mechanical refrigerating units.

Between Waseca and Altoona, in car B with only one of the refrigerating units operating most of the time, air and commodity temperatures changed little (tables 5 and 15). Bottom commodity temperatures were lower than top commodity temperatures. Recorded air temperatures were substantially below the 0° F. thermostat setting, indicating the thermostat was out of calibration (fig. 4). Recorded bottom air temperatures were about the same as top

Table 5.--Average temperature changes in car B while in transit, Waseca, Minn., to Altoona, Pa., August 18-21, 1956

Location	Date and time	Commodity			Air		
		Top	Bottom	Average	Top	Bottom	Average
		°F.	°F.	°F.	°F.	°F.	°F.
Waseca	Aug.18, 2:00 p.m.	-1.4	-6.7	-4.3	-6.5	1/	1/
Altoona . . .	Aug.21, 8:10 a.m.	.4	-7.2	-4.1	-6.5	1/	1/
Change . . .		+1.8	-.5	-.2	0.0	1/	1/

1/ Instrument failed to record temperatures.

air temperatures, and top air temperatures at the air intake, (A) end of the car, were higher than those recorded in front of the fan or at the opposite end (B).

With the lowering of the thermostat setting to -10° F. at Altoona, commodity and air temperatures declined rapidly (table 6). Both units operated from here to destination. In a period of 24 hours, the average commodity temperature declined from -4.1° to -8.3°, and the average recorded air temperature at the top of the load was lowered 5°. Bottom commodity temperatures remained substantially below top commodity temperatures.

Table 6.--Average temperature changes in car B while in transit, Altoona, Pa., to Jersey City, N. J., August 21-22, 1956

Location	Date and time	Commodity			Air		
		Top	Bottom	Average	Top	Bottom	Average
		°F.	°F.	°F.	°F.	°F.	°F.
Altoona . . .	Aug. 21, 8:10 a.m.	.4	-7.2	-4.1	-6.5	1/	1/
Jersey City .	Aug. 22, 8:00 a.m.	-5.0	-11.0	-8.3	-11.5	1/	1/
Change . .		-5.4	-3.0	-4.2	-5.0	1/	1/

1/ Instrument failed to record temperatures.

Throughout the trip, temperatures were maintained at close to 0° F. or below (tables 7 and 15). The lack of uniformity between top and bottom temperatures may be attributed to the fact that the cold air entered under the load at one end of the car (fig. 2). Commodity and air temperature increases reflected the heat pickup as the air progressed around and over the load. Maximum commodity temperatures were recorded at the top door left and right side positions (table 15), indicating there may have been a poor air seal around the door. This, along with the indicated uneven cold air circulation around the load, contributed to the wide differences in minimum and maximum recorded temperatures. In-transit differences in commodity temperatures averaged 12.3°. Because the thermometer recording bottom air temperatures in this car failed to function, the extremes in air temperatures are not known.

Table 7.--Average temperature changes in car B while in transit, Waseca, Minn., to Jersey City, N. J., August 18-22, 1956

Location	Date and time	Commodity			Air		
		Top	Bottom	Average	Top	Bottom	Average
		°F.	°F.	°F.	°F.	°F.	°F.
Waseca . . .	Aug. 18, 2:00 p.m.	-1.4	-6.7	-4.3	-6.5	1/	1/
Jersey City .	Aug. 22, 8:00 a.m.	-5.0	-11.0	-8.3	-11.5	1/	1/
Change . . .		-3.6	-4.3	-4.0	-5.0	1/	1/

1/ Instrument failed to record temperatures.

Loading of car C was completed at 3:15 p.m., August 17, and the loaded car remained on the siding until 2:00 p.m. the following day, or about 23 hours (table 8 and fig. 5). Average commodity temperature had increased from 0° to 12.2° F. in the process of loading, the top averaging 18.2° and the bottom 7.2°. By 9:40 p.m. on the same day, the average commodity temperature was lowered to +0.2° and by 2:00 p.m. on August 18, when the cars were picked up, the average commodity temperature had increased to 2.7°. Average air temperatures were slightly above the thermostat setting of 0°, and some minor inaccuracy in the thermostat is indicated (fig. 5). The recorded temperatures reveal the car refrigeration system had sufficient capacity to lower temperatures rapidly.

Table 8.--Average temperature changes in car C, loaded and awaiting transit at Waseca, Minn., August 17-18, 1956

Date and time	Commodity			Air		
	Top	Bottom	Average	Top	Bottom	Average
	°F.	°F.	°F.	°F.	°F.	°F.
August 17:						
3:15 p.m. . .	18.2	7.2	12.2	38.0	60.0	49.0
6:30 p.m. . .	3.0	1.7	2.3	7.5	8.0	7.8
9:40 p.m. . .	2.0	-1.3	+.2	2.5	4.0	3.3
August 18:						
6:30 a.m. . .	2.6	3.3	3.0	-.5	3.0	1.3
10:30 a.m. . .	2.2	3.2	2.7	0	3.0	1.5
2:00 p.m. . .	2.2	3.2	2.7	0	2.5	1.3
Change	-16.0	-4.0	-9.5	-38.0	-57.5	-47.7

From Waseca to Altoona, air and commodity temperatures changed little (table 9). Bottom and top temperatures were about the same. Air and commodity temperatures generally were uniform throughout the load; this can be attributed to the forced air circulation cooling the load from each end of the car (fig. 3). Recorded air temperatures remained slightly above the 0° F. thermostat setting (fig. 5).

Table 9.--Average temperature changes in car C while in transit, Waseca, Minn., to Altoona, Pa., August 18-21, 1956

Location	Date and time	Commodity			Air		
		Top	Bottom	Average	Top	Bottom	Average
		°F.	°F.	°F.	°F.	°F.	°F.
Waseca . .	Aug. 18, 2:00 p.m.	2.2	3.2	2.7	0	2.5	1.3
Altoona . .	Aug. 21, 8:10 a.m.	2.8	3.5	3.2	2.0	2.0	2.0
Change . .		+.6	+.3	+.5	+2.0	-.5	+.7

At Altoona, the thermostat was adjusted to -10° F. and commodity and air temperatures declined rapidly (table 10). During this 24-hour in-transit period to Jersey City, the average commodity temperature declined from 3.2° to -2.1°, and the average recorded air temperature was lowered from 2.0° to -4.0°. Temperatures recorded after the thermostat was adjusted downward to -10° indicated the refrigerating system had ample reserve capacity and was capable of maintaining below 0° temperatures.

Table 10.--Average temperature changes in car C while in transit, Altoona, Pa., to Jersey City, N. J., August 21-22, 1956

Location	Date and time	Commodity			Air		
		Top	Bottom	Average	Top	Bottom	Average
		°F.	°F.	°F.	°F.	°F.	°F.
Altoona . . .	Aug. 21, 8:10 a.m.	2.8	3.5	3.2	2.0	2.0	2.0
Jersey City .	Aug. 22, 8:00 a.m.	-3.6	-.8	-2.1	-6.0	-2.0	-4.0
Change . .		-6.4	-4.3	-5.3	-8.0	-4.0	-6.0

Table 11 reveals that both commodity and air temperatures declined significantly in transit, but that top temperatures were lower than bottom temperatures. The constant, forced circulation of cold air from each end of the car over the top of the load contributed to this difference (fig. 3). Minimum and maximum temperatures in test packages throughout the load showed limited variation during transit, averaging about 4.7° F. (table 16). Variation in minimum-maximum air temperatures averaged 4.9°. This general uniformity in temperatures resulted from the even circulation of cold air around the load.

Table 11.--Average temperature changes in car C while in transit, Waseca, Minn., to Jersey City, N. J., August 18-22, 1956

Location	Date and time	Commodity			Air		
		Top	Bottom	Average	Top	Bottom	Average
		°F.	°F.	°F.	°F.	°F.	°F.
Waseca . . .	Aug. 18, 2:00 p.m.	2.2	3.2	2.7	0	2.5	1.3
Jersey City	Aug. 22, 8:00 a.m.	-3.6	-.8	-2.1	-6.0	-2.0	-4.0
Change . .		-5.8	-4.0	-4.8	-6.0	-4.5	-5.3

Table 12 lists the recorded commodity temperatures in the center of the load at the midquarter-centerline position in each of the cars. When the commodity temperatures had recovered from the heat gained during loading, the temperatures at this position continued to drop until they reached -5° F. in the mechanical cars and -3° in the water-ice car, considerably lower than the temperatures recorded at other positions in outer layers of the load. But it must be understood that the test packages at this position were

Table 12.--Commodity temperatures recorded at the midquarter-centerline position in each carload of frozen corn, August 17-22, 1956

Place	Date and time	Commodity temperature in car - A	B	C
		°F.	°F.	°F.
	August 17:			
Waseca, Minn.	11:15 a.m.	-	7	-
	2:00 p.m.	-	3	-
	3:15 p.m.	-	-	8
	6:30 p.m.	14	2	-2
	9:40 p.m.	2	3	-5
	August 18:			
	6:30 a.m.	0	-4	1
	10:30 a.m.	-2	-4	1
	2:00 p.m.	-2	-5	1
Rochester, Minn.	7:40 p.m.	-2	-5	1
	August 19:			
Sparta, Wis.	4:45 a.m.	-2	-5	2
So. Beaver Dam, Wis.	10:20 a.m.	-2	-5	2
Proviso, Ill.	4:10 p.m.	-2	-5	2
	August 20:			
Dolton, Ill.	10:15 a.m.	-3	-5	2
Logansport, Ind.	1:20 p.m.	-3	-5	2
Columbus, Ohio	9:10 p.m.	0	-4	2
	August 21:			
Pitcairn, Pa.	3:10 a.m.	0	-5	2
Altoona, Pa.	8:10 a.m.	0	-4	2
Enola Yard, Pa.	1:30 p.m.	0	-5	1
Waverly, N. J.	7:45 p.m.	2	-5	0
	August 22:			
Harsimus Cove, N. J.	12:15 a.m.	2	-5	-1
Jersey City, N. J.	8:00 a.m.	2	-5	-2

handled while the thermometer bulbs were inserted and that the packages immediately around them were not. The packages surrounding the test packages also were held in the warehouse in pallet blocks, and it is assumed they had been placed in interior stacks in pallet loads where, after removal from the plate-freezing line at temperatures lower than the 0° maintained in the storage room, they continued to hold temperatures lower than that level. Temperatures of test packages rapidly declined to a level below those of the packages in outer layers of the same loads.

The average commodity temperature in exterior load test packages for car A at Jersey City, N. J., was +14.3° F., as compared to the midload test package temperature of +2° F. In car B the average commodity temperature of packages in the exterior of the load at destination was -8.3°, while the interior temperature was -5°. At destination, car C had an average commodity temperature of -2.1° in packages in the exterior of the load. The interior midquarter-centerline package had a temperature of -2°.

In car A, the insulating effect of surrounding packages maintained the low product temperature in the midquarter-centerline test package. Table 12 reveals, however, that the temperature in this package was rising gradually, having increased 5° F. in the final 43 hours of the in-transit test. Thus, the package was absorbing some of the heat gain of surrounding packages.

The commodity temperature of the test package in the interior of the load in car B remained constant at -5° F. while in transit. Lowering the thermostat setting to -10° at Altoona, Pa., apparently had no effect on the temperature of this package, although temperatures at the bottom quarterline dropped to -9° and -11°. The fact that the temperature was higher in the test package in the interior of the load at destination than the average temperature of packages in the exterior indicates that the colder air did not have sufficient time to penetrate to this package. The solid floor racks and the fact that the colder air came in direct contact only with top-of-load packages may be the reason why the temperature of the midload package was not affected during this 24-hour period.

While initial product temperatures within the midquarter centerline position package in car C were rather erratic, after the car was in transit the temperature was stabilized at about 1° or 2° F. below the average load temperature. The effect of lowering the thermostat setting to -10° is reflected in the lower temperatures in the midload test package during the final 24 hours of the trip; the temperature of this midload package declined 4°, just 1.3° less than the decline of the average commodity temperature in exterior test packages (table 10). The slatted floor racks may have contributed to the more rapid penetration of the colder air to the inner part of the load in this car.

Throughout the trip condensation was noted on the exterior sheathing of all 3 cars, indicating a loss of refrigeration. This condensation appeared around the doors and in strips along the lower sections of the cars at approximately the interior floor level. The condensation covered areas varying from 6-inch strips 4 feet long to small patches 3 inches in diameter.

FUEL AND ICE CONSUMPTION

The data for fuel, ice, and salt consumption cover the quantities used during the preliminary cooling test and during the transit test. The total value at tariff rates of the ice and salt put in car A was $214.97 and that consumed was $133.67 (table 13). However, the tariff charge for standard refrigeration, as provided on this shipment, was $142.59, and this latter amount is what the shipper paid for the service. The actual costs of the ice and salt to the carriers were not available.

The twin gasoline-type, diesel-burning engines in car B operated intermittently 18 and 94 hours, respectively, or a total of 112 hours. They consumed 123.5 gallons of fuel, or 1.1 gallons per hour. At 16 cents per gallon for diesel fuel, the out-of-pocket cost for refrigeration was $19.76.

Table 13.--Ice and salt used by car A, August 16-21, 1956

Location	Date and time	Ice			Salt		
		Quantity	Price per ton	Cost	Quantity	Price per cwt	Cost
		Tons	Dollars	Dollars	Pounds	Dollars	Dollars
Waseca, Minn.	Aug. 16, 6:00 p.m	7.4	5.70	42.18	4,400	1.14	50.16
" "	Aug. 17, 3:00 p.m	3.4	5.70	19.38	2,040	1.14	23.25
" "	Aug. 18, 5:00 p.m	1.0	5.70	5.70	600	1.14	6.84
Adams, Wis.	Aug. 19, 8:30 a.m	1.9	5.70	10.83	1,140	1.14	13.00
Blue Island, Ill.	Aug. 20, 1:00 a.m	1.2	6.61	7.90	720	1.14	8.21
Huntington, Pa.	Aug. 21, 10:45 a.m	2.0	6.91	13.84	1,200	1.14	13.68
Subtotal . .		16.9	-	99.83	10,100	-	115.14
Less: Estimated quantity in car at destination.		6.5	1/5.91	37.41	3,850	1/1.14	43.89
Total		10.4		62.42	6,250		71.25

1/ Average price.

The single diesel engine in car C operated continuously for 130.9 hours and consumed 97.4 gallons of fuel, or 0.75 gal./hr. At 16 cents per gallon, the out-of-pocket cost for refrigeration was $15.58.

Fuel, ice, and salt consumption represents only one of many items in total operating costs. The original cost of the mechanical refrigerator car is much higher than the cost of a standard ice-bunker fan car, and the amortization cost over its service life would be greater. Maintenance costs of mechanical cars would be higher than for ice cars. However, data on these additional costs are not available.

Each of the mechanical refrigeration units was stopped during loading and at points en route where servicing was required.

CONCLUSIONS AND RECOMMENDATIONS

The preliminary cooling test indicates the wide variations that may be expected in time required to precool mechanically refrigerated cars, depending upon the capacities of their respective refrigeration units. One car reached 0° F. in 7 hours, while the other required 16 hours. Shippers should allow ample time for precooling and should make certain that interior car temperatures are at the desired level before loading. Heat remaining in the car will be absorbed by the cargo and will increase the load on the refrigerating unit.

The transit test reveals that commodity temperatures in cartons around the exterior of the load are affected rapidly by changes in air temperatures, but that temperatures of packages in the interior of the load change slowly Frozen food should be loaded only when it is at the proper temperature and should be tightly stacked to minimize the exposed surface. The capacity of the refrigerating unit to remove heat should be regarded by the shipper as a means of maintaining proper temperatures around the load, not as a means for lowering product temperatures while in transit.

As was demonstrated in this test, the product will absorb ambient heat during loading, even when precautions are taken. Initial temperature readings of the commodity after loading ranged up to 24° F., and air temperatures inside the cars increased to 65°. To minimize heat gain, the commodity should be moved rapidly from warehouse to car and car-door curtains should be used around loading conveyors, as was done in these tests. Closing of car doors and operation of refrigerating units are essential during extended interruptions in loading. In the water-ice car, portable motors should have been available to operate the fans, both to precool the car and to maintain forced cold air circulation within the loaded car while it remained on the siding at Waseca.

The ambient heat gained during loading was removed rapidly in the mechanical cars, but in the water-ice car, commodity temperatures in test cartons never were lowered to zero. Observation indicated all 3 cars were in need of some repair. A faulty draft gear, loose ice hatch doors, poor door seals, and a leakage in the disposal pipe for defrost water were noted. The thermostats on both of the mechanical cars needed calibration to maintain temperatures at which they were set. The fan at one end (B) of the water-ice car did not operate, although efforts were made by the railroad to repair it. The condensation on the exterior sheathing of all 3 cars indicated there was a loss of refrigeration. This was particularly evident around the doors. Door seals should be inspected frequently to see that they fit properly and are replaced as necessary.

Proper mixing of ice and salt in the car bunkers is necessary if maximum cold temperatures are to be maintained. The salt should be evenly dispersed throughout the crushed ice, or it will congeal and settle to the bunker bottom, preventing air circulation through the ice. Shippers should insist that bunkers be clear of salt accumulations, particularly when frozen food is to be loaded.

Air circulation seemed adequate in both mechanical cars, and test data indicated each had ample capacity to maintain proper temperatures for frozen food. Temperatures were more uniform in car C and out-of-pocket refrigeration costs were slightly lower in this car.

Temperatures maintained in the water-ice car were not at the level desired for frozen foods. The commodity temperatures were fairly uniform, but never approached zero. The outer layers warmed to a dangerous level, and the interior of the load had a gradual rise in temperature. Although the performance of this car probably would have been somewhat better had both fans been operating, it seems unlikely from the recorded temperatures that they would have been brought down to a safe level for frozen foods. It should be noted that the commodity temperatures shown in table 14 were taken at the "A" end of the car, where the fan was operative. No record was made of the temperatures at the "B" end. It is recommended that mechanical cars be used in preference to water-ice cars when low temperatures are desired, particularly in hot weather.

APPENDIX

Table 14.--Temperatures recorded during transit test of frozen corn in car A, Waseca, Minn., to Jersey City, N. J., August 17-22, 1956

Location	Date and time	Outside temp.	Air temperatures						Commodity temperatures											Top commodity			Bottom commodity		
			Top			Bottom																			
			TBCL (A)	TBCL (B)	Av.	BBCL (A)	BBCL (B)	Av.	TBCL	TQCL	TDCL	TDRS	TDLS	BBCL	BBLS	BQRS	BQLS	BDRS	BDLS	Max.	Min.	Av.	Max.	Min.	Av.
		°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.
	August 17:																								
Waseca, Minn.	6:30 p.m.	80	67	57	62.0	17	8	12.5	18	24	19	22	17	6	6	5	8	20	16	24	14	20.0	20	5	10.2
Waseca, Minn.	9:40 p.m.	70	40	43	41.5	9	2	5.5	16	20	19	20	17	7	6	5	9	14	13	20	16	18.4	14	5	9.0
	August 18:																								
Waseca, Minn.	6:30 a.m.	63	28	37	32.5	6	-1	2.5	16	20	18	18	19	6	8	6	10	11	10	26	16	18.2	11	6	8.5
Waseca, Minn.	10:30 a.m.	65	25	35	30.0	6	-2	2.0	17	16	17	18	18	6	8	9	10	11	10	18	16	17.2	11	6	9.0
Waseca, Minn.	2:00 p.m.	70	23	27	25.0	6	-2	2.0	16	16	17	18	17	6	8	7	9	11	10	18	16	17.0	11	6	8.5
Rochester, Minn........	7:40 p.m.	58	18	24	21.0	7	-2	2.5	14	12	15	16	17	6	8	8	10	11	12	17	12	14.8	12	6	9.2
	August 19:																								
Sparta, Wis.	4:45 a.m.	48	13	22	17.5	9	0	4.5	12	11	14	15	16	7	9	9	10	12	12	16	11	13.6	12	7	9.8
So. Beaver Dam, Wis....	10:20 a.m.	65	15	21	18.0	11	1	6.0	11	10	12	13	15	8	10	9	10	12	13	15	10	12.2	12	8	10.3
Proviso, Ill.	4:10 p.m.	67	9	20	14.5	12	1	6.5	9	10	11	12	13	8	10	9	10	12	12	13	9	11.0	12	8	10.2
	August 20:																								
Dolton, Ill.	10:15 a.m.	72	18	22	20.0	8	-2	3.0	14	10	13	14	17	8	10	10	11	13	13	17	10	13.6	13	8	10.8
Logansport, Ind.	1:20 p.m.	80	10	21	15.5	10	2	6.0	11	10	13	14	15	8	10	10	11	14	14	15	10	12.6	14	8	11.2
Columbus, O.	9:10 p.m.	64	9	18	13.5	12	2	7.0	10	11	13	13	14	9	11	10	10	13	13	14	10	12.2	13	9	11.0
	August 21:																								
Pitcairn, Pa.	3:10 a.m.	61	10	17	13.5	12	2	7.0	10	11	11	12	13	10	12	10	10	13	13	13	10	11.4	13	10	11.3
Altoona, Pa.	8:10 a.m.	63	10	15	12.5	12	3	7.5	10	11	11	12	14	11	12	10	11	13	13	14	10	11.6	13	10	11.7
Enola Yd., Pa.	1:30 p.m.	80	10	17	13.5	12	3	7.5	10	11	12	12	14	10	13	11	11	14	14	14	10	11.8	14	11	12.2
Waverly, N. J.	7:45 p.m.	65	10	17	13.5	12	3	7.5	10	11	12	12	13	11	13	11	11	14	14	13	10	11.6	14	11	12.3
	August 22:																								
Harsimus Cove, N. J.	12:15 a.m.	66	16	17	16.5	11	3	7.0	12	14	13	14	15	11	13	11	12	14	14	15	12	13.6	14	11	12.5
Jersey City, N. J	8:00 a.m.	80	18	20	19.0	11	2	6.5	14	17	15	16	17	11	14	12	13	14	14	17	14	15.8	14	11	13.0

Table 15.--Temperatures recorded during transit test of frozen corn in car B, Waseca, Minn., to Jersey City, N. J., August 17-22 1956

Location	Date and time	Outside temp.	Air temperatures						Commodity temperatures											Top commodity			Bottom commodity		
			Top			Bottom																			
			TBCL (A)	TBCL (B)	Av.	BBCL (A)	BBCL (B)	Av.	TBCL	TQCL	TDCL	TDRS	TDLS	BBCL	BBLS	BQRS	BQLS	BDRS	BDLS	Max.	Min.	Av.	Max.	Min.	Av.
		°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.
	August 17:																								
Waseca, Minn.	11:15 a.m.	74	50	47	48.5	1/	16	1/	16	13	5	23	19	3	5	4	0	2	5	23	5	15.2	5	0	3.2
Waseca, Minn.	2:00 p.m.	80	11	1	6.0	-	-1	-	7	5	3	9	9	3	3	4	0	-2	0	9	3	6.6	3	-2	1.3
Waseca, Minn.	6:30 p.m.	80	0	-5	-2.5	-	-4	-	5	6	10	12	11	3	-1	4	4	-1	0	12	5	8.8	4	-1	1.5
Waseca, Minn.	9:40 p.m.	70	-1	-7	-4.0	-	-4	-	5	-1	7	10	5	3	-1	4	5	-4	-3	10	-1	5.2	5	-4	0.7
	August 18:																								
Waseca, Minn.	6:30 a.m.	63	-3	-10	-6.5	-	-7	-	-2	-4	0	1	1	-7	-7	-6	-4	-5	-5	1	-4	-0.8	-4	-7	-5.6
Waseca, Minn.	10:30 a.m.	65	-3	-8	-5.5	-	-8	-	-2	-4	-1	1	1	-7	-7	-6	-4	-5	-7	1	-4	-1.0	-4	-7	-6.0
Waseca, Minn.	2:00 p.m.	70	-4	-9	-6.5	-	-10	-	-2	-5	-1	0	1	-8	-8	-7	-5	-5	-7	1	-5	-1.4	-5	-8	-6.7
Rochester, Minn.	7:45 p.m.	58	-5	-8	-6.5	-	-8	-	0	-3	-1	2	3	-8	-8	-7	-5	-5	-7	3	-3	0.2	-5	-8	-6.7
	August 19:																								
Sparta, Wis.	4:45 a.m.	48	-6	-8	-7.0	-	-9	-	0	-4	-2	0	2	-9	-9	-7	-5	-5	-7	2	-4	-0.8	-5	-9	-7.0
So. Beaver Dam, Wis.	10:20 a.m.	65	-6	-9	-7.5	-	-11	-	0	-4	-2	1	3	-11	-9	-8	-6	-7	-8	3	-4	-0.4	-6	-11	-8.2
Proviso, Ill.	4:10 p.m.	67	-4	-7	-5.5	-	-7	-	0	-3	-3	1	3	-9	-9	-7	-6	-5	-5	3	-3	-0.4	-5	-9	-6.8
	August 20:																								
Dolton, Ill.	10:15 a.m.	72	-7	-9	-8.0	-	-8	-	-1	-4	-3	0	2	-10	-7	-8	-6	-7	-8	2	-4	-1.2	-6	-10	-7.6
Logansport, Ind.	1:20 p.m.	80	-5	-9	-7.0	-	-8	-	-1	-4	-3	-1	2	-9	-7	-8	-6	-6	-7	2	-4	-1.4	-6	-9	-7.2
Columbus, O.	9:10 p.m.	64	-5	-10	-7.5	-	-10	-	0	-4	-3	1	5	-11	-9	-8	-6	-5	-7	5	-4	-0.2	-5	-11	-7.7
	August 21:																								
Pitcairn, Pa.	3:10 a.m.	61	-4	-12	-8.0	-	-12	-	-1	-3	-2	2	5	-10	-10	-8	-6	-4	-7	5	-3	-0.2	-4	-10	-7.5
Altoona, Pa.	8:10 a.m.	63	-4	-9	-6.5	-	-8	-	-2	-3	-2	1	4	-11	-9	-7	-6	-3	-7	4	-3	0.4	-3	-11	-7.2
Enola Yard, Pa.	1:30 p.m.	80	-7	-15	-11.0	-	-12	-	-6	-6	-3	-4	0	-9	-10	-10	-7	-7	-8	0	-6	-3.8	-7	-10	-8.5
Waverly, N.J.	7:45 p.m.	65	-8	-14	-11.0	-	-11	-	-6	-7	-3	-4	0	-13	-11	-10	-8	-7	-9	0	-7	-4.0	-7	-13	-9.7
	Aug. 22:																								
Harsimus Cove, N.J.	12:15 a.m.	66	-10	-15	-12.5	-	-12	-	-7	-7	-4	-5	-1	-13	-11	-11	-8	-8	-10	-1	-7	-4.8	-8	-13	-10.2
Jersey City, N. J.	8:00 a.m.	80	-9	-14	-11.5	-	-9	-	-6	-7	-5	-5	-2	-13	-13	-11	-9	-9	-11	-2	-7	-5.0	-9	-13	-11.0

1/ Instrument failed to record temperatures.

Table 16.--Temperatures recorded during transit test of frozen corn in car C, Waseca, Minn., to Jersey City, N. J., August 17-22, 1956

Location	Date and time	Out-side temp.	Air temperatures						Commodity temperatures											Top commodity			Bottom commodity		
			Top			Bottom																			
			TBCL (A)	TBCL (B)	Av.	BBCL (A)	BBCL (B)	Av.	TBCL	TQCL	TDCL	TDRS	TDLS	BBCL	BBLS	BQRS	BQLS	BDRS	BDLS	Max.	Min.	Av.	Max.	Min.	Av.
		°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.
	August 17:																								
Waseca, Minn.	3:15 p.m.	79	20	56	38.0	65	55	60.0	16	20	21	16	18	4	5	6	0	10	18	21	16	18.2	18	0	7.2
Waseca, Minn.	6:30 p.m.	80	5	10	7.5	8	8	8.0	2	1	4	3	5	0	1	-2	-2	2	11	5	1	3.0	11	-2	1.7
Wseca, Minn.	9:40 p.m.	70	2	3	2.5	5	3	4.0	1	0	2	2	5	-2	-1	-4	-5	0	4	5	0	2.0	4	-5	-1.3
	August 18:																								
Waseca, Minn.	6:30 a.m.	63	-2	1	-.5	4	2	3.0	2	2	4	3	2	4	4	3	3	4	2	4	2	2.6	4	2	3.3
Waseca, Minn.	10:30 a.m.	65	-2	2	0.0	4	2	3.0	2	2	3	2	2	3	5	2	3	4	2	3	2	2.2	5	2	3.2
Waseca, Minn.	2:00 p.m.	70	-2	2	0.0	3	2	2.5	2	2	3	2	2	3	5	2	3	4	2	3	2	2.2	5	2	3.2
Rochester, Minn.	7:40 p.m.	58	-2	2	0.0	3	2	2.5	2	2	4	2	3	3	5	2	3	4	2	4	2	2.6	5	2	3.2
	August 19:																								
Sparta, Wis.	4:45 a.m.	48	-1	3	1.0	3	2	2.5	2	2	4	3	4	3	5	3	3	4	3	4	2	3.0	5	3	3.5
So. Beaver Dam, Wis.	10:20 a.m.	65	-1	4	-1.5	3	2	2.5	2	2	3	2	4	3	5	2	3	3	4	4	2	2.6	5	2	3.3
Proviso, Ill.	4:10 p.m.	67	-1	4	-1.5	3	1	2.0	2	1	3	2	3	3	5	2	3	4	4	3	1	2.2	5	2	3.5
	August 20:																								
Dolton, Ill.	10:15 a.m.	72	-1	3	1.0	3	1	2.0	2	2	3	2	2	3	4	2	3	4	4	3	2	2.2	4	2	3.3
Logansport, Ind.	1:20 p.m.	80	-1	3	1.0	3	1	2.0	2	2	3	2	3	3	4	3	3	4	4	3	2	2.4	4	3	3.5
Columbus, O.	9:10 p.m.	64	-1	3	1.0	3	1	2.0	2	2	4	2	4	4	3	3	3	4	4	4	2	2.8	4	3	3.5
	August 21:																								
Pitcairn, Pa.	3:10 a.m.	61	0	4	2.0	3	1	2.0	3	2	4	2	3	4	6	3	4	4	2	4	2	2.8	6	2	3.8
Altoona, Pa.	8:10 a.m.	63	0	4	2.0	3	1	2.0	2	2	4	2	4	3	6	2	3	4	3	4	2	2.8	6	2	3.5
Enola Yard, Pa.	1:30 p.m.	80	0	3	1.5	2	-2	0.0	0	-1	2	1	1	3	6	2	2	2	4	1	-1	0.6	6	2	3.2
Waverly, N.J.	7:45 p.m.	65	-3	-2	-2.5	1	-4	-1.5	-5	-5	-1	-1	-2	2	5	0	2	0	2	-1	-5	-2.8	5	0	1.8
	August 22:																								
Harsimus Cove, N. J.	12:15 a.m.	66	-4	-4	-4.0	1	-6	-2.5	-6	-6	-2	-2	-3	2	5	-1	0	-1	1	-2	-6	-3.8	5	-1	1.0
Jersey City, N. J.	8:00 a.m.	80	-7	-5	-6.0	0	-4	-2.0	-4	-4	-3	-4	-3	0	3	-3	-1	-3	-1	-3	-4	-3.6	3	-3	-0.8

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